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An Advanced Distributed Simulation (ADS)
Test Implementation Methodology

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An Advanced Distributed Simulation (ADS) Test Implementation Methodology

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INTRODUCTION

The Joint Advanced Distributed Simulation (JADS) Joint Test and Evaluation program was chartered by the Office of the Secretary of Defense in October 1994 to investigate the utility of advanced distributed simulation (ADS) technologies for support of test and evaluation (T&E). Among other things, the charter tasked JADS to "identify the critical constraints, concerns, and methodologies when using ADS for T&E."[1] JADS has gained considerable experience in planning and conducting distributed tests and is using that experience to develop methodologies which will be passed as legacy products to the T&E community.

A previous paper[2] described a general test planning methodology which incorporated excursion loops for the examination of ADS alternatives. The steps are used to assist testers in deciding if ADS-based testing makes sense for specific T&E applications. An example of a case in which ADS implementation is appropriate would be for the mission-level evaluation of a system in which the system under test (SUT) interacts with a number of other systems and man-in-the-loop interactions are involved. In this case, a live test involving a large number of players would not be affordable, and using a digital system model (DSM) for the entire scenario would not produce credible results for the human interactions and decision-making processes.

This paper outlines a methodology developed by JADS for implementing ADS-based T&E, once the decision has been made to use ADS. The implementation methodology follows the steps given in the Defense Modeling and Simulation Office (DMSO) High Level Architecture (HLA) Federation Development and Execution Process (FEDEP) model[3] and amplifies them by adding lessons learned from JADS testing experience. Key methodology activities discussed are the careful determination of test objectives and all appropriate requirements before design of the ADS architecture begins. Also, the importance of integration testing is emphasized. The methodology is designed to take the tester through all aspects of ADS-based test planning, designing, development/construction, check-out, execution, and reporting.

FEDEP MODEL

The FEDEP model groups the activities needed to develop and execute a distributed test into six steps:

- Step 1: The test sponsor or evaluator and the distributed test development team define and agree on a set of objectives and document what must be accomplished to achieve those objectives.

- Step 2: A representation of the real world domain of interest is developed and described in terms of a set of required objects and interactions.

- Step 3: Distributed test participants (federates) are determined, and required functionalities are allocated to the participants.

- Step 4: The Federation Object Model (FOM) is developed (if HLA is implemented), participant agreements on consistent databases/algorithms are established, and modifications to federates are implemented (as required).

- Step 5: All necessary distributed test implementation activities are performed, and testing is conducted to ensure interoperability requirements are being met.

- Step 6: The distributed test is executed, outputs are generated, and results provided.

The FEDEP model breaks the six steps into activities, as shown in Table 1.

Table 1. Distributed Test Planning and Implementation Activities.

STEP	ACTIVITIES
1. Define Distributed Test Objectives	1.1 Identify Needs 1.2 Develop Objectives
2. Develop Conceptual Model	2.1 Develop Scenario 2.2 Perform Conceptual Analysis 2.3 Develop Test Requirements
3. Design Distributed Test	3.1 Select Participants 3.2 Allocate Functionality 3.3 Prepare Plan
4. Develop Distributed Test	4.1 Develop FOM 4.2 Establish Participant Agreements 4.3 Implement Participant Modifications
5. Integrate and Test Architecture	5.1 Plan Execution 5.2 Integrate and Test ADS Architecture
6. Execute Distributed Test and Analyze Results	6.1 Execute Distributed Test 6.2 Process Output 6.3 Prepare Results

The test implementation methodology presented here uses the FEDEP model as a framework and amplifies the activities using lessons learned from JADS testing experience. The full methodology is documented in a JADS special report.[4] This paper will focus on the following key activities as an illustration of the overall methodology:
- Activity 2.3 Develop Test Requirements
- Activity 3.1 Select Participants
- Activity 3.2 Allocate Functionality
- Activity 3.3 Prepare Plan

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- Activity 4.2 Establish Participant Agreements
- Activity 5.1 Plan Execution
- Activity 5.2 Integrate and Test ADS Architecture

DEVELOP TEST REQUIREMENTS

Before the distributed test architecture can be designed, detailed test requirements must be defined. These requirements should be based on the distributed test objectives, should be directly testable, and provide the implementation level guidance needed to design and develop the distributed test. The test requirements will also be the basis for the criteria for evaluating test results. Major top-level requirements which should be addressed include the following:
- Fidelity requirements. The fidelity requirements for all players represented in the distributed test scenarios must be determined. The required fidelity depends upon the maturity of the SUT, the SUT test objectives, and the nature of the interactions between the SUT and the other players.
- Interaction requirements. Determine the data types which must be exchanged among players to permit interactions, including entity state data, tactical messages, launch and detonation indications (if appropriate), and trial start and stop notification.
- Latency requirements. Determine the maximum acceptable latency and latency variations for each pair of interacting players. The maximum latency requirement will be determined by how closely coupled the interactions are and by the maximum allowable error in the location of one player as perceived by the other
- Data reliability requirements. Determine the maximum acceptable level of ADS-induced errors, such as dropout rate and out-of-order data messages. The allowable errors may vary with data types.
- Data analysis requirements. Draft a preliminary data management and analysis plan (DMAP) which details the analysis approach for each test objective. From the DMAP determine which data must be collected and the analysis techniques to be applied.

After all these requirements have been developed, the capability of the support agencies (e.g., simulation or range facilities, networking and engineering team) to support the test must be clearly stated and documented, such as by a Statement of Capability (SOC). The SOC documents the set of requirements and provides a clear statement of the support agency's capabilities, constraints, and limitations in meeting those requirements.

The support agencies also need to create an integrated, detailed work breakdown structure (WBS) early in the program which is consistent with the SOC. It is also important to have accurate cost estimates allocated against the WBS tasks in order to help program management decisions.

SELECT PARTICIPANTS

According to the FEDEP model, the purpose of this activity is to determine the suitability of individual player representations (e.g., simulations, HWIL labs, or live players/ranges) to become participants in the distributed test. The input to this activity is the conceptual model (developed in

Activity 2.2) which is a description of the players, their actions, and any interactions between players that need to be included in the distributed test.

This selection is driven primarily by the following factors:
- perceived ability of potential representations to represent the players' behavior and the interactions specified in the conceptual model.
- fidelity requirements for each player.
- managerial constraints, such as availability, cost, schedule, and security considerations.
- technical constraints, such as VV&A status and portability.
- For live players, the selection of particular test ranges is also driven by considerations of range instrumentation quality and quantity and data processing capability.

ALLOCATE FUNCTIONALITY

According to the FEDEP model, the purpose of this activity is to allocate the responsibility to represent the entities and actions in the conceptual model to the participants. This activity will allow for the assessment of whether the set of selected participants provides the full set of required functionality or whether one or more of the representations will need to be enhanced to meet the distributed test requirements.

Requirements need to be allocated to the participants before the architecture can be designed and before the requirements for modifying existing player representations or designing new ones can be determined. These allocated requirements include the following:
- Data requirements.
  - Determine the data exchange rates among the players.
  - Determine the time-space-position information (TSPI) accuracy and smoothness requirements for live players. This determination depends on the test objectives and the data input requirements of the player receiving the TSPI data.
  - Determine the requirement for data time stamp accuracy. If latency is to be measured, the time stamps must be accurate to the required latency determination accuracy. For most applications, an accuracy of 0.1 milliseconds is more than adequate. Note that the time sources which determine the time stamps at distributed locations must be synchronized to within the required time stamp accuracy.
  - Determine the classification of the data and any security handling requirements. This is generally driven by the SUT security classification guide.
  - Document all data exchanges with an interface control document (ICD).
- Data synchronization requirements. Determine the requirement for synchronizing multiple data inputs at a receiving node.
- Real-time data processing requirements. These might include the processing needed to achieve the required TSPI accuracy for live player, telemetry processing, processing needed for synchronization of multiple data inputs at a receiving node, and processing needed to achieve latency compensation.
- Data collection/instrumentation requirements. This includes data which must be recorded for support of post-test analysis.

These allocated requirements are used to assess the capabilities of the player representations selected or to determine design requirements for any missing representations. This assessment may reveal the need to modify the selected representations. Requirements for potential modifications are determined as follows:

- Determine if any simulation modifications will be necessary to utilize external inputs.
- Determine if any simulation modifications will be necessary to generate required outputs.
- Determine if any range data processing modifications will be necessary to meet TSPI accuracy, smoothness, and latency requirements.
- Determine if any facility modifications will be required for a replay capability which can be used during integration testing.

If missing player representations must be developed, the additional requirements are used for the design requirements. The decision to design and develop a new representation can have severe cost and schedule impacts on the distributed test, since this can be the single largest cost of an ADS-based test. For example, the JADS End-to-End (ETE) Test needed a ground emulation of the Joint Surveillance Target Attack Radar System aircraft radar subsystem and operator work stations, and no adequate simulation existed. Thus, the decision was made to develop the required simulation, and its cost was about 40% of the total ETE Test budget.

PREPARE PLAN

According to the FEDEP model, the purpose of this activity is to develop a coordinated plan to guide the development, test, and execution of the distributed test. The following documents are needed:

- A detailed test plan which includes a configuration management plan.
- A detailed DMAP which specifies the data requirements, data sources, analysis procedures, and the analysis products required to accomplish each test objective.
- A detailed VV&A plan which includes integration testing to verify architecture performance.
- A detailed ICD which specifies all data to be passed between simulations/range facilities. This data specification includes data content, timing, formats, and coordinate systems (including all coordinate transformation equations). The ICD is essential for ensuring successful integration of the simulations/range facilities and must be rigorously enforced.

ESTABLISH PARTICIPANT AGREEMENTS

According to the FEDEP model, the purpose of this activity is to establish all agreements between participants necessary for a fully consistent, interoperable, distributed simulation environment. During this activity, the participant interaction requirements are finalized, including the following:

- Determine the data protocols to be used.
  - Decide if standard protocols (e.g., DIS PDUs) are to be used or if it would be advantageous to keep data in formats/coordinate systems generated by the players.
  - Identify any data exchanged between players which is best kept in its tactical protocol.
- Interface requirements. Note that linking of facilities using ADS can require significant interface hardware and software development. ADS implementation is not "plug and play."

- Network interface units (NIUs) of some sort are necessary if two simulations cannot communicate directly in a common language and on a common timeline. Determine coordinate transformation and dead reckoning requirements.
- If HLA is to be implemented, interfaces will be required between all federates (e.g., player representations, range facilities, etc.) and the runtime infrastructure (RTI).

Operational issues and policies are also addressed and resolved, including the following:
- Terrain data base requirements. Determine requirements for a common terrain data base, including resolution and level of detail.
- Post-test data management requirements. Determine the source and quantity of all data to be recorded at each recording location. A distributed test with numerous trials can generate a large volume of data at distributed locations. Without careful planning, key data may not be collected and/or transmitted to the analysis center, and data collected at the sites may not be in a useful form for centralized analysis. An efficient method for retrieving the data to a central analysis facility is by use of the network links.
- Test control and monitoring requirements.
    - Develop the test control concept, including a determination of the central control location and the test coordination location at each distributed node/facility. Determine the techniques to be used for control of any live players.
    - Determine the display and monitoring requirements.
        - Determine the voice communications requirements for effective control and monitoring of the distributed test.

PLAN EXECUTION

According to the FEDEP model, the purpose of this activity is to define and develop the full set of information required to support the distributed test execution. Detailed network design should be completed during this activity, although design work should begin as soon as the participant allocated requirements have been defined. Early definition of network requirements allows for timely selection of hardware and software alternatives and allows enough time to acquire the right components through government channels and contracts. Key considerations in finalizing the network design include the following:
- Determine if data from each node will be broadcast, multicast, or unicast (transmitted point-to-point).
- Determine if data are to be transmitted using best effort or reliable procedures, based on data transport reliability requirements.
- Determine the network security approach to be implemented. Detailed procedures for secure/encrypted operations must be developed, and approval for their use must be obtained from the designated approval authority.
- Determine the WAN bandwidth requirement.
- Conduct surveys of each site to be linked by the network.

The test and VV&A plans should be refined, especially the integration test plan section. In refining the integration test plan, step-by-step systematic integration testing procedures need to be developed and should address the following:

- Procedures for verifying any simulation/range facility modifications or any new player representations in a systematic stand-alone fashion.
- Procedures for initially testing each WAN link separately. Testing should begin at the channel service unit (CSU)/data service unit (DSU) level to make sure that communications work at the lowest level.
- Procedures for testing each simulation-to-simulation connection with all network nodes connected.
- Procedures for testing the voice communications with all equipment and personnel as in the actual test.

Also, detailed test control procedures and a security test and evaluation plan should be developed. The test control procedures should include checklists covering activities for 24 hours prior, 4 hours prior, 1 hour prior, during the mission, and post-test. Existing stand-alone facility/range procedures serve as a starting point for developing the checklists. The system integrator uses these to develop new checklists which interleave the activities at each facility and include those unique to the distributed test environment.

INTEGRATE AND TEST ADS ARCHITECTURE

This activity combines the separate FEDEP activities of "Integrate Federation" and "Test Federation" because of the close connection between the two. An iterative "test-fix-test" approach is recommended, so that the integration and test activities become closely interrelated. According to the FEDEP model, the purpose of these activities is to bring all of the distributed test participants into a unifying operating environment and to test that they can all interoperate to the degree required to achieve the test objectives.

The ADS test architecture is installed during this activity using the following steps:
- The WAN to be used to link the facilities is selected and procured. This includes determining whether a DoD-sponsored network can support the test requirements or if commercial leased lines must be used.
- The network hardware to be used is selected, procured, and installed, including routers, CSUs/DSUs, mulitplexers, encryptors, etc.
- The interfaces necessary for linking are built/procured in accordance with the requirements developed during Activity 4.2.
- Test control hardware and software are selected, procured, and installed based on the requirements developed in the previous activity.
- Network analysis/monitoring tools are selected and procured and/or developed.

Key testing steps during this activity include the following:
- Perform compliance testing, as specified in the VV&A plan. Test each facility/node individually to ensure that ADS capability and any required modifications (including software) have been correctly implemented.
- Perform integration testing, as specified in the integration test plan.
  - Check out interfaces and facility modifications with linking between pairs of nodes.
  - Baseline the performance of the network with no loading from the simulations/players.

- Test performance of critical portions of the network under loading representative of test conditions to be used.
  - Use an iterative "test-fix-test" approach, including replay of trials to diagnose problems and verify fixes.
- Perform risk reduction missions. The purpose of these fully linked missions is to exercise all parts of the distributed test to ensure that they operate as intended. The early risk reduction missions are invaluable for identifying problems before the actual test. The later missions are used to verify fixes and serve as rehearsals for the formal test execution.
- Perform validation, as specified in the VV&A plan.

SUMMARY

Experience and lessons learned from JADS testing have been used to develop a methodology for the implementation of ADS-based testing. This paper only briefly overviews selected methodology activities; the complete detailed implementation methodology is available from the JADS web page at http://www.jads.abq.com until 1 March 2001. After that date, refer requests to HQ AFOTEC/HO, 8500 Gibson Blvd SE, Kirtland Air Force Base, New Mexico 87117-5558 (phone: 505-846-2579), or the JT&E Program Office Technical Library, 2001 North Beauregard St. Suite 800, Alexandria, Virginia 22311 (phone: 703-578-8222). The methodology has been designed as a practical and useful tool for future users of this technology and constitutes a major part of the legacy that JADS will transition to the T&E community.

REFERENCES

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